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REVIEW

METHODS FOR EXPRESSING THE ASSOCIATIONS OF DIFFERENT SPECIES

A recent publication on Malaria and Malarial Mosquitoes of the Far East[1] possesses much interest for ecologists on account of its containing a proposed "new method for studying the typical distribution of species," set forth on pages 7–24. This method is designed to show the relations of one species to others with which it is associated, and was devised by Dr. Hacker to illustrate the associations of Anophelines in the Malay States.

It consists (*a*) in adding to the number of times a species is found alone, the number of times it is found with each of the other species in a certain number of breeding places, this total being the number of "association units" available for that species; and (*b*) in expressing the component parts of this total as percentages; the percentage association of one species with each of the other species is termed its "association value."

Out of a number of illustrations of his method given by Dr. Hacker, we select the following:

Anopheles hyrcanus was found by itself 487 times, with *A. barbirostris* 169 times, with *A. vagus* 84 times, and with each of ten other species 78, 51, 46, 19, 16, 7, 5, 5, 3, 2 and 1 times respectively. The sum of these times is 973, which is the total number of association units. The association value of *A. hyrcanus* with *A. barbirostris* is 169 over 973 or 17.4 percent. (All the data used refer to the *larvae only* of these mosquitoes.)

Dr. Hacker's summary and conclusions are as follows:—

"(*a*) The method generally used for studying distribution is to collect descriptions of the breeding places of a species, in the hope that a description of the typical breeding place of that species may be evolved. Apart from the confusion that arises from the number of characters which require description, this method is defective, in the first place since it depends on personal impressions, and in the second place since these personal impressions are based on natural characters which vary from time to time. The method introduced in this volume is based on the number of times a given species is found with each of the other species in a certain number of breeding places. It is not based on personal impressions.

"(*b*) A peculiar merit of this method is that it enables past observations, of whatever dimensions, to be epitomised in a series of figures (the association values) showing the relative distributions of any given species.

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[1] Federated Malay States Malaria Bureau Reports. Vol. II. November, 1920. By H. P. Hacker, M.D., B.Sc. (Lond.) Medical Entomologist, Federated Malay States. Printed by Waterlow & Sons, Limited, London, Dunstable & Watford, 1921. 8vo., 47 pp., plans and diagrams. [The reviewer is indebted to the Editor of the Review of Applied Entomology, London, for his copy.]

" (*c*) This epitome can be used as a standard for estimating the probability of other species being found in company with any given species. When, therefore, any one species is found, it will be possible to prophesy what other species may be expected to be present in the same place. To prophesy with any degree of accuracy, the observations must be based on the widest experience, both in respect of number of observations and types of locality.

" (*d*) This epitome can also be used as a standard by which the distribution of any species can be measured in any area. The practical value of such a standard is that if the distribution in a newly investigated area does not conform to the standard, local causes must be sought for.

" (*e*) The epitome, however, merely reflects the past experience relating to the various species, and is much affected by the number of observations on each species. For example, on the few occasions a rare species is found. a certain species might always be present in its breeding place. Yet the association values of the common species would not show this close association merely because of the rarity of the associate; but the association values of the rare species would show the association.

"(*f*) The ideal way of overcoming this weakness would be to increase the data of the species with few records, until the basis of data for each species is of the same order of magnitude, but this is obviously impossible when rare species are being dealt with. At the present stage of the investigation the weakness may be overcome by taking into consideration the association values of both species in considering the relationship between them. Later, however, when the figures become adequate, a simple formula to express both sides of the relationship may be found.

" (*g*) In spite of the weakness of the method as a means for grouping the species into faunae, referred to in sections (*e*) and (*f*), the figures, even as they are expressed at the present stage of the investigation, show that the species may be grouped in [a certain] manner, and it is of interest to note that this grouping agrees closely with what is generally known about the breeding places of the species."

Prof. S. A. Forbes has called the reviewer's attention to a method which he devised in 1907[2] for determining what he styled the "coefficient of association" of any two species, the rule for which he stated as follows:

"Multiply the number [*a*] of collections made from the common area of the species by the number [*d*] containing one or more representatives of both; multiply the number [*b*] of collections containing one or more representatives of one of the species by the number [*c*] containing one or more of the other; and divide the first product [*ad*] by the second [*bc*]. The quotient will be the coefficient of association $\left[\frac{a\ d}{b\ c}\right]$."

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[2] On the Local Distribution of certain Illinois Fishes: an Essay in Statistical Ecology. Bull. Ill. State Lab. Nat. Hist. VII; article VIII. See also Journ. Ecol. III, pp. 12–13. 1915.

On comparing these two methods it is evident that Dr. Hacker's does not consider the quantity *a* of Prof. Forbes' where, being in the numerator and the largest quantity involved, it gives the coefficient a value of more than unity. The largest quantity (the sum of the number of times etc.) in Dr. Hacker's method is in the denominator, and the resulting association value is less than unity. It follows that in the latter method the association value is proportional to the number of times a given species (B) is associated with another species (C), a relation which does not hold in Prof. Forbes' formula. Prof. F. H. Safford, who has kindly looked into the mathematics of these two methods for the reviewer, calls attention to the facts that there is no relation between the coefficients of the two authors, and that neither method uses the number of individuals in the collections investigated. Dr. Hacker has appreciated the bearing of this omission, as is evidenced by his remarks under paragraphs *e* and *f* quoted above. He lays much stress on finding that most of the species studied by him have a larger association value each for itself than for any associated species, a condition which does not appear in Prof. Forbes' tables. Dr. Hacker's method involves fewer calculations than Prof. Forbes'. It will be interesting to test both of them by data derived from other groups of organisms.

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